

MAY 14 1969

Log in FM
Route to 253

NASA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-88

April 18, 1969

NZ

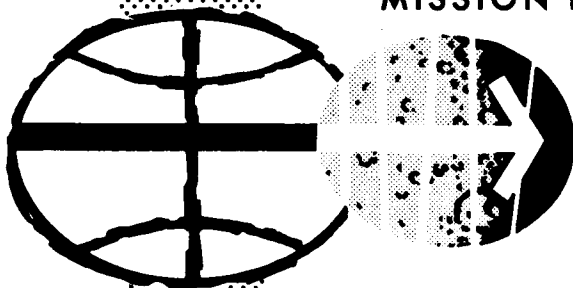
APOLLO 9 POSTJETTISON
SEPARATION MANEUVER
FOR THE APS BURN TO DEPLETION

Internal Note No. 69-FM-88



Flight Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

(NASA-TM-X69699) APOLLO 9 POSTJETTISON
SEPARATION MANEUVER FOR THE APS BURN TO
DEPLETION (NASA) 24 p

N74-70506

Unclas
00/99 16204

MSC INTERNAL NOTE NO. 69-FM-88

PROJECT APOLLO

APOLLO 9 POSTJETTISON SEPARATION MANEUVER
FOR THE APS BURN TO DEPLETION

By Michael E. Donahoo
Flight Analysis Branch

April 18, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: Charlie C. Allen
Charlie C. Allen, Chief
Flight Analysis Branch

Approved: John P. Mayer
John P. Mayer, Chief
Mission Planning and Analysis Division

FIGURES

Figure		Page
1	Motion of the CSM relative to the LM ascent stage for CSM RCS separation burns at varying times prior to APS burn to depletion ignition	
	(a) 5 minutes prior to ignition	5
	(b) 8 minutes prior to APS ignition	6
	(c) 10 minutes prior to APS ignition	7
	(d) 12 minutes prior to APS ignition	8
	(e) 15 minutes prior to APS ignition	9
	(f) 17 minutes prior to APS ignition	10
2	Motion of the CSM relative to the LM ascent stage for separation burns initiated subsequent to jettison; varying separation and jettison ΔV 's	
	(a) Down range versus vertical range	11
	(b) Down range versus cross range	12
3	Separation distance between the CSM and LM ascent stage at APS ignition	13
4	Position and orientation of the LM ascent stage and CSM at physical separation and at RCS ignition	14
5	CSM time line from LM ascent stage separation until the APS burn to depletion ignition	15
6	Motion of the CSM relative to the LM ascent stage following the out-of-plane separation burn (SM RCS) from a stationkeeping position	16
7	Motion of the CSM relative to the LM ascent stage following the in-plane separation burn (SM RCS) from a stationkeeping position	17
8	Separation distance of the CSM relative to the LM ascent stage for various separation ΔV 's	
	(a) Down range versus radial range	18
	(b) Down range versus cross range	19

Figure

Page

9	Total separation distance of the CSM from the LM ascent stage for varying separation ΔV 's applied during stationkeeping versus time from initial separation	20
---	---	----

APOLLO 9 POSTJETTISON SEPARATION MANEUVER

FOR THE APS BURN TO DEPLETION

By Michael E. Donahoo

1.0 SUMMARY AND INTRODUCTION

The purpose of this internal note is to present the preflight analysis that was conducted and to document the recommendations made concerning the CSM separation burn performed subsequent to jettison of the LM ascent stage and prior to the APS burn to depletion. The recommended procedures were implemented into the nominal sequence of events for the Apollo 9 mission.

For the Apollo 9 mission, nominal jettison of the LM ascent stage occurred at $101^{\text{h}}30^{\text{m}}00^{\text{s}}$ ground elapsed time (g.e.t.), approximately 30 minutes prior to the ascent propulsion system (APS) burn to depletion ignition. Prior to jettison, the command and service modules (CSM) oriented the ascent stage to its inertial burn attitude; the ascent stage remained in inertial hold through ignition. The CSM then separated by firing the tunnel severance pyrotechnics which imparted a relative separation velocity with a possible range from 0.4 fps to 1.5 fps which placed the CSM to the north and below the ascent stage. The CSM crew then maneuvered the spacecraft to a stationkeeping position down range of the ascent stage and performed formation flying until $101^{\text{h}}38^{\text{m}}14^{\text{s}}$ g.e.t. at which time a 3.0-fps postjettison separation maneuver moved the CSM first above and then behind the ascent stage. At APS ignition, the CSM was positioned approximately 4425 feet behind and 3975 feet above the ascent stage. The CSM 3.0-fps separation burn allowed up to 2.0-fps uncertainty in the stationkeeping relative velocities and still insured a safe position at APS ignition.

At $101^{\text{h}}59^{\text{m}}00^{\text{s}}$ g.e.t., the APS engine was to ignite and burn until fuel depletion. Local attitudes of the ascent stage at ignition were planned to be 47.4° in yaw to the north and 15.3° pitched down below the local horizontal. The attitude insured that the ascent stage was increasing the separation distance between it and the CSM at all times; therefore, no recontact possibilities existed.

2.0 ANALYSIS

Changes in postjettison separation maneuver constraints and requirements resulted in the development of a number of candidate procedures by which the separation burn could be performed. These procedures varied from stationkeeping positions of the CSM both in front and behind the ascent stage to procedures that used no stationkeeping. Each procedure will be presented in the following discussion along with the constraints and relative motion for each.

2.1 CSM Stationkeeping Position Behind the Ascent Stage

The initial approach toward construction of a postjettison separation maneuver was concerned with maneuvers that would place the CSM in a position behind the ascent stage for reasons of photography and observation [figs. 1(a) through 1(f)]. Ejection was to occur at 101^h47^m00^s g.e.t. (approximately 12.0 min prior to APS ignition). The CSM would be in a position 1500 feet behind and 940 feet above the ascent stage at APS ignition [fig. 1(d)] if the 3.0-fps burn was performed by use of the four SM RCS -X jets at an attitude of 45° north in yaw and pitch down 60° below the local horizontal.

With the additional constraint that the recommended separation procedure be good for contingencies in which the APS burn was delayed until a later time, the above method became unacceptable because of recontact. The 3.0-fps maneuver was performed in an attitude such that a component of the ΔV was in the retrograde direction. The resultant motion caused the CSM eventually to move below and ahead of the ascent stage because the retrograde ΔV placed the CSM in a lower orbit with a decreased orbital period.

2.2 No Stationkeeping Procedure

Analyses were also conducted to determine what type procedure would be necessary to eliminate the stationkeeping exercise involved in the previous sequence and, at the same time, insure that the CSM be in a favorable position relative to the ascent stage for delayed APS ignition contingencies. First, the RCS separation must be performed in a prograde direction to insure that the CSM moves behind the ascent stage and remains there. Second, the undocking ΔV produced by jettison must be considered when determining which ΔV to use in the separation burn. Indications were that the jettison ΔV could vary in range from 0.4 fps to 1.50 fps. Simulations were conducted by the use of the jettison ΔV

variations, and a range of separation ΔV 's were performed at a local attitude of 45° yaw to the south and pitch up 120° from the local horizontal. The four +X SM RCS thrusters were fired to produce the separation ΔV and to place the CSM above and behind the ascent stage at APS ignition (fig. 2).

The relative motion (fig. 3) indicates that the low jettison ΔV 's present the greatest problems with this type maneuver because less separation distance is produced during the time from jettison to the separation burn. The in-plane separation range components are small; however, the out-of-plane component of separation precludes recontact.

2.3 Stationkeeping in Front

The final approach to the problem was to analyze separation maneuvers performed from a stationkeeping position in front of the LM (figs. 4 and 5). The maneuver would eliminate the effects of the jettison ΔV on the separation burn (as did the stationkeeping behind) and would allow the crew to perform a posigrade burn away from the ascent stage. Relative motion plots [figs. 6 and 7, 8(a) and 8(b)] indicate that the CSM would be in a position behind and above the ascent stage at nominal APS ignition and would remain behind for contingencies in which the APS ignition was delayed. In figures 6 and 7, the CSM was pitched down 60° below the velocity vector. In figure 6 the maneuver was performed with 135° yaw to the north, and in figure 7, the maneuver was performed with 180° of yaw.

Additional data were generated to determine the effect on the relative motion of performance of the separation burn at an attitude of 135° yaw to the south and pitched down 30° from the local horizontal. The cross range and the radial range motion are presented in figures 8(a) and 8(b), respectively, as a function of the down-range position. The total separation range between the CSM and the ascent stage is presented in figure 9 as a function of elapsed time from separation. The passive state of the LM allowed the figure to be used to obtain a specified separation distance at APS ignition by selection of an elapsed time from RCS ignition that obtained the desired distance.

3.0 CONCLUSIONS

Each of the previously discussed techniques for separation of the CSM from the ascent stage subsequent to jettison and prior to the APS burn to depletion was adequate from the standpoint of recontact. The

first technique, stationkeeping behind, had the advantage that it was relatively easy to attain the position because at jettison placed the CSM behind the ascent stage. Another important advantage was the crew's ability to control the distance behind the ascent stage with small ΔV 's initiated close to APS ignition. The major disadvantage was that eventually the spacecraft would move in front of the ascent stage if the APS burn was delayed.

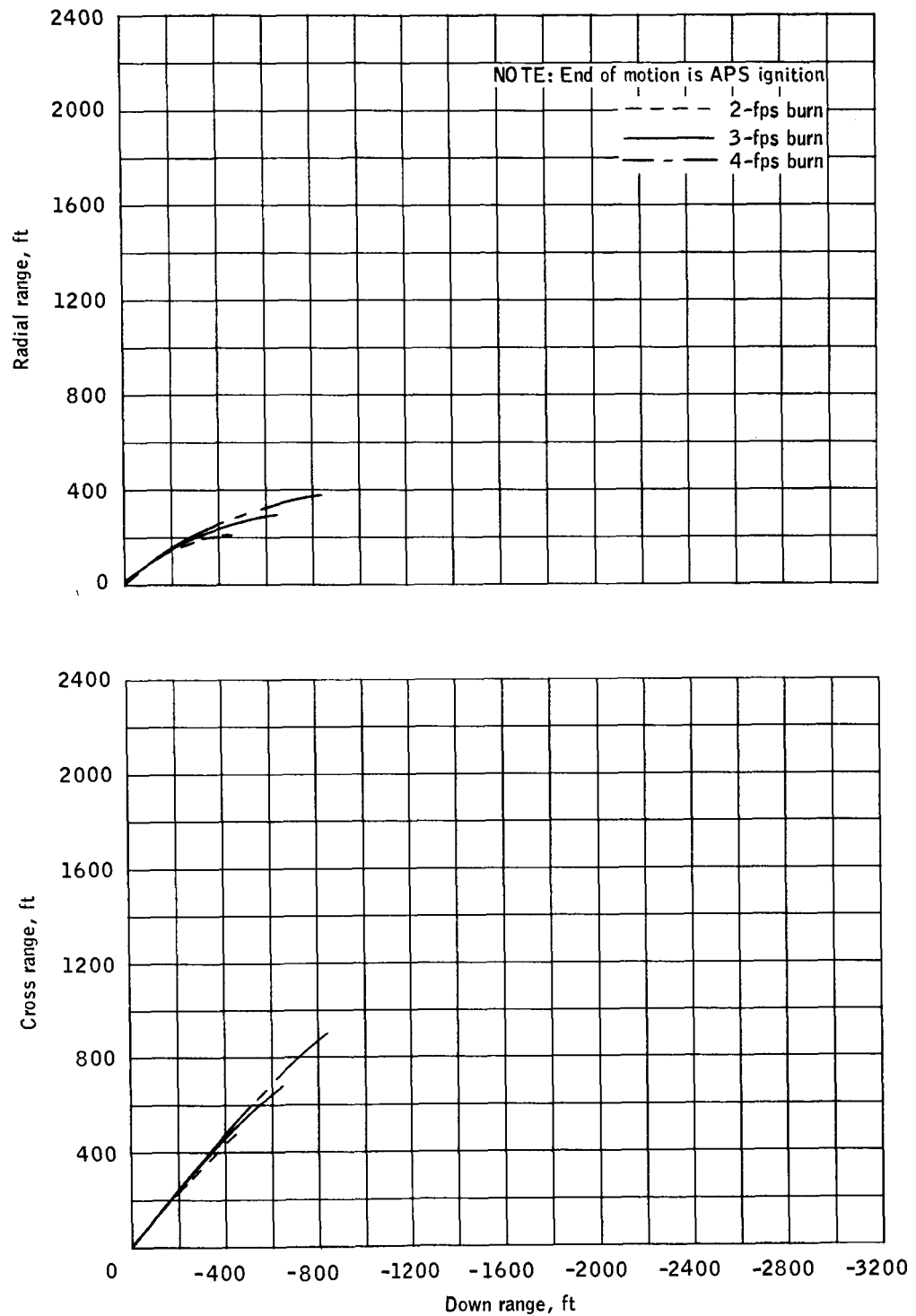
The second technique, which involved a posigrade separation burn after the jettison without stationkeeping, had the advantage that it eliminated concern about relative range rates which might be generated during stationkeeping; however, the ΔV produced by the jettison pyrotechnics must be considered to determine the ΔV for the separation burn. The ΔV produced by the pyrotechnic separation results in a significant uncertainty in separation distance at APS ignition and when considering separation, distance is important. The in-plane separation miss distances at closest approach were in some instances as low as 100 feet, but the out-of-plane component was large enough to preclude recontact.

The final procedure involved initiation of the postjettison separation burn from a stationkeeping position down range of the ascent stage. The crew had to fly the spacecraft around the ascent stage to the stationkeeping position because of their position relative to the ascent stage at jettison. A posigrade separation burn continually increased the separation distance and placed the CSM behind the ascent stage at APS ignition and allowed it to stay behind for contingencies in which the APS ignition time was delayed. Once again, the uncertainties involved in stationkeeping relative range rates must be considered. These range rates have been assigned a value of ± 1.0 fps for this analysis.

4.0 RECOMMENDATIONS

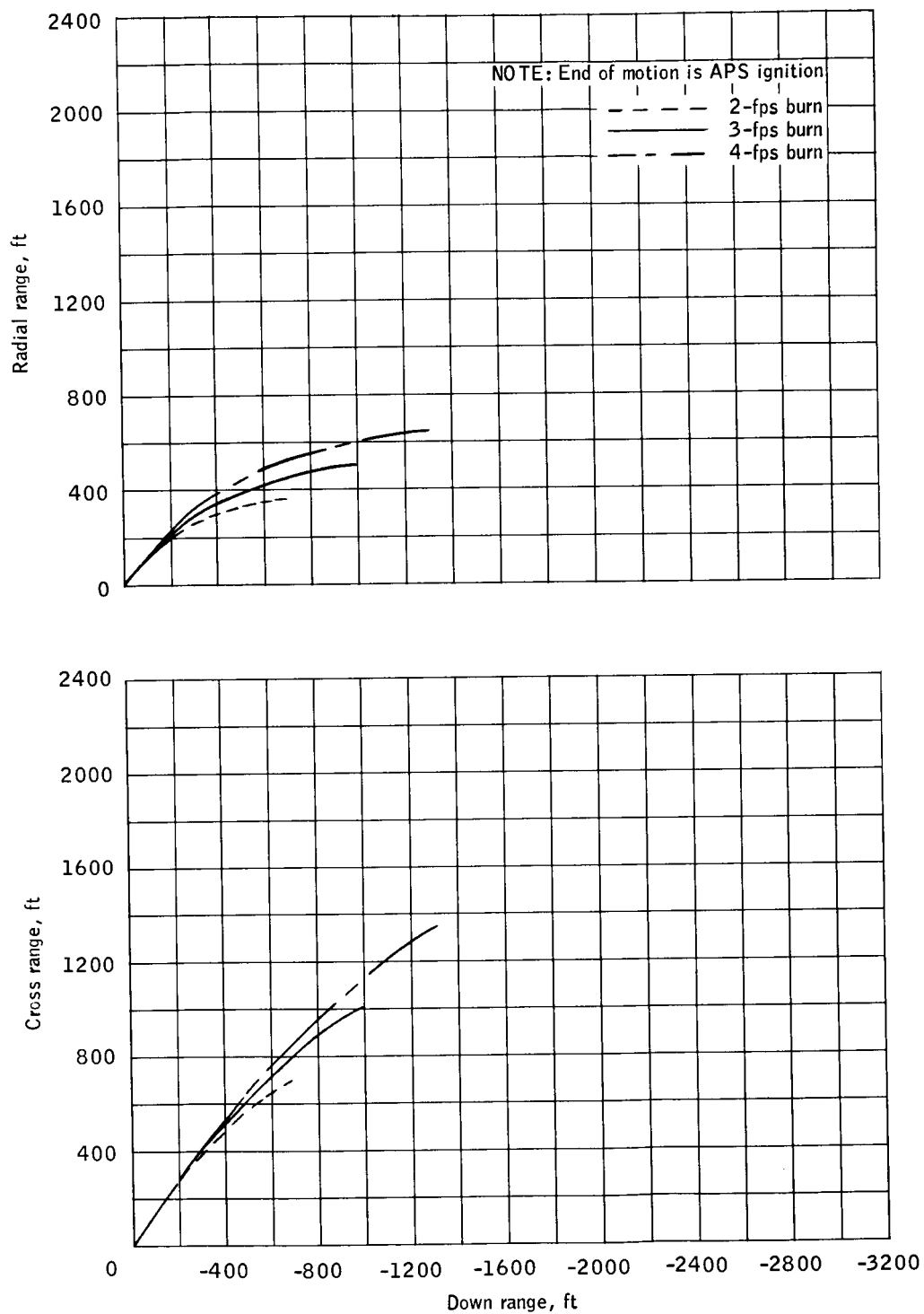
In consideration of the previous discussion and the preference of the Apollo 9 crew, the procedure that involved the postjettison separation burn applied from a stationkeeping position in front of the ascent stage was recommended (fig. 5). At initiation of the four-jet -X CSM RCS 3.0-fps burn, the CSM should have been at an attitude of yawed south 135° and pitched down 60° from the velocity vector. This attitude corresponds to the spacecraft gimbal angles of $IGA = 120.452^\circ$, $MGA = 28.793^\circ$, and $OGA = 68.289^\circ$.

The 3.0-fps ΔV produced adequate separation distance between the CSM and ascent stage at APS ignition even for stationkeeping uncertainties of 1.0 fps in a direction opposite the separation burn. However, note that the relative motion presented in this analysis for the recommended procedure was a result of the separation burn being performed with no relative range rates at a position 100 feet in front of the ascent stage and at the same altitude as the descent stage.



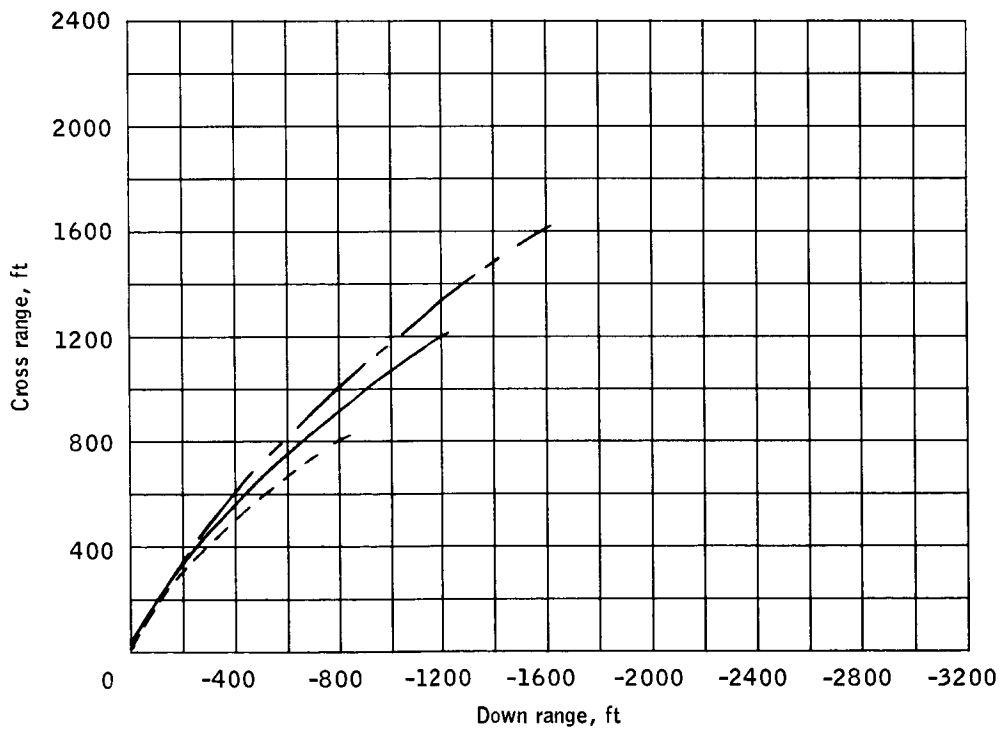
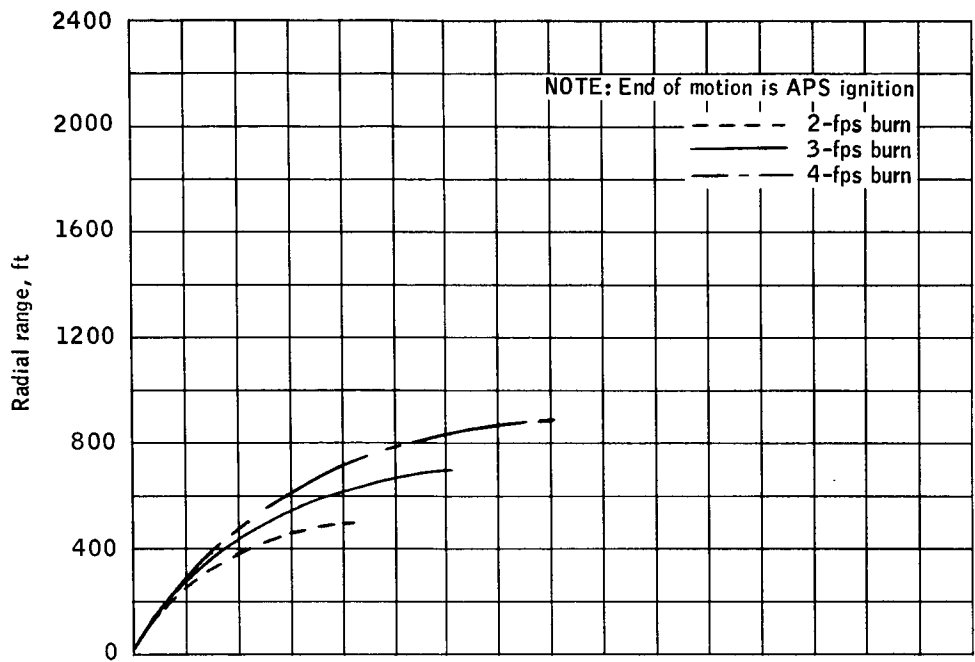
(a) 5 minutes prior to ignition.

Figure 1.- Motion of the CSM relative to the LM ascent stage for CSM RCS separation burns at varying times prior to APS burn to depletion ignition.



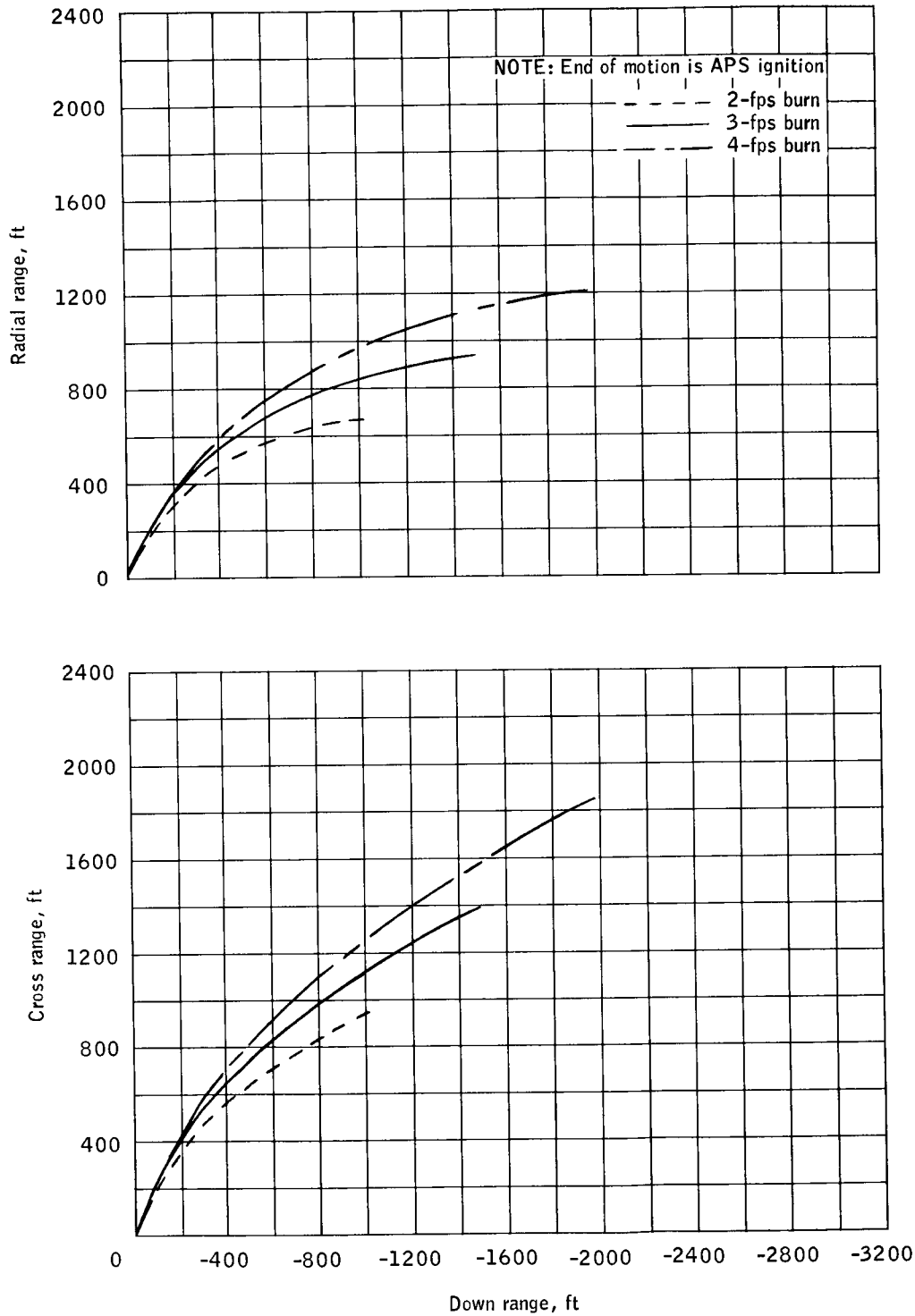
(b) 8 minutes prior to APS ignition.

Figure 1. - Continued.



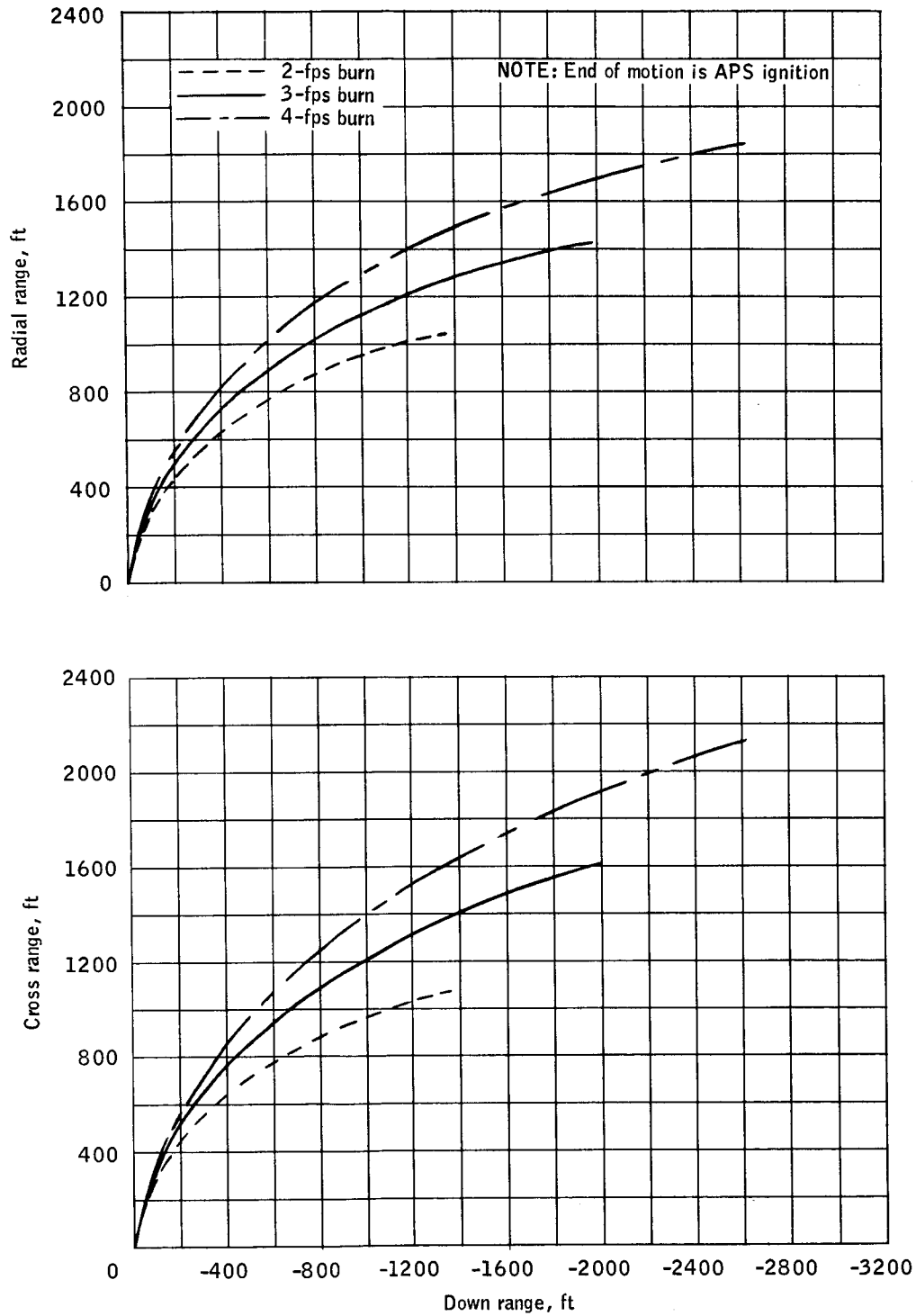
(c) 10 minutes prior to APS ignition.

Figure 1.- Continued.



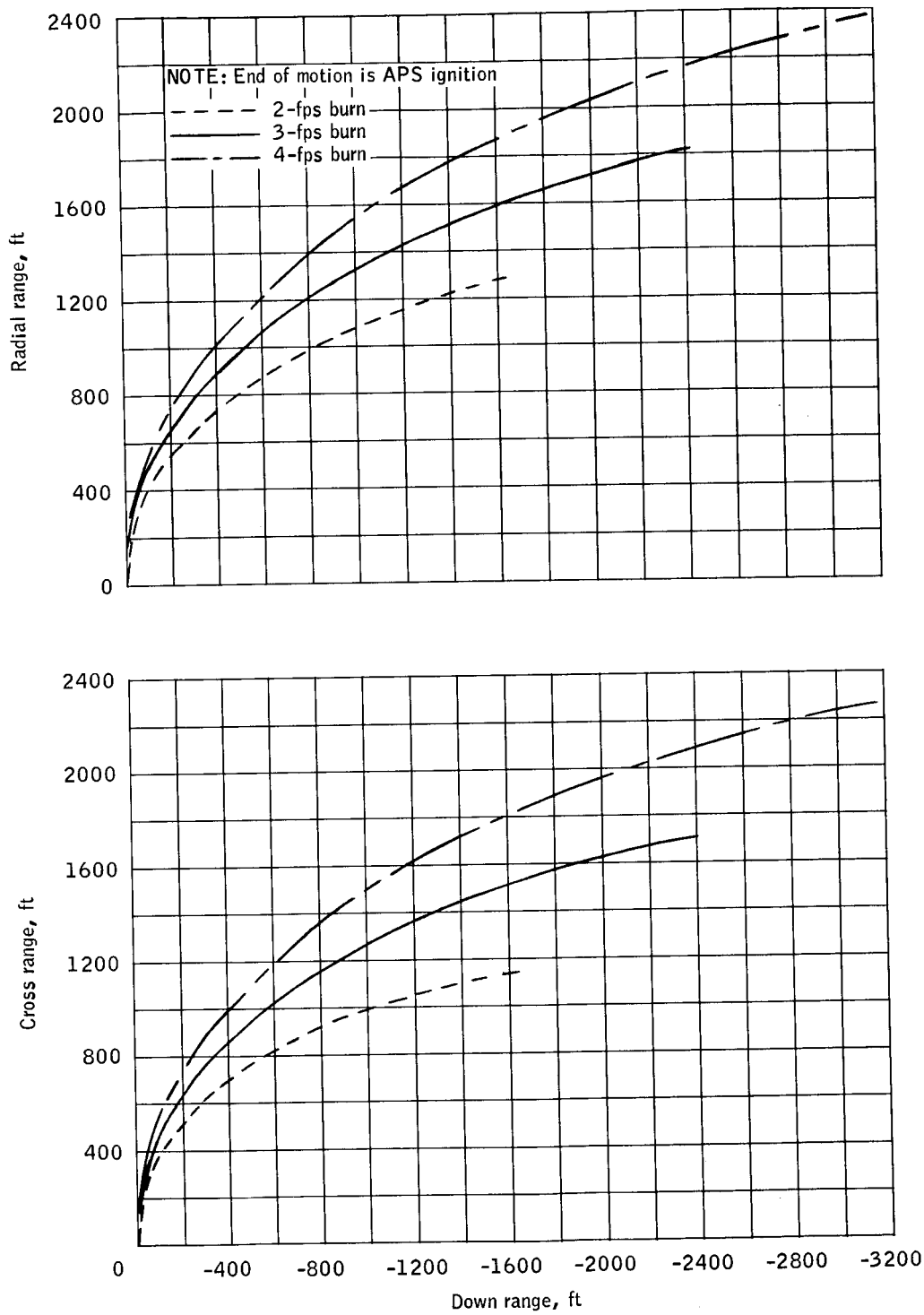
(d) 12 minutes prior to APS ignition.

Figure 1.- Continued.



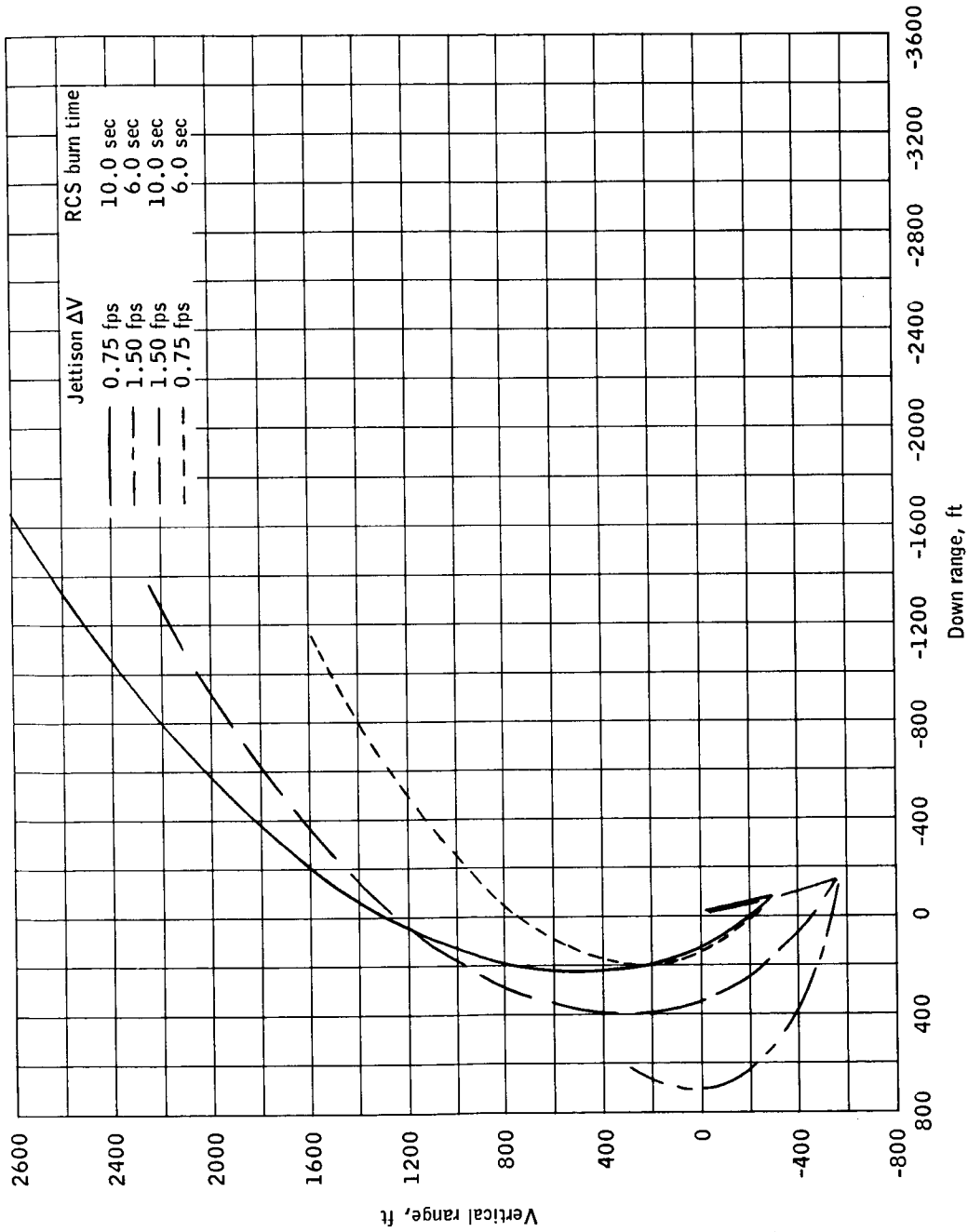
(e) 15 minutes prior to APS ignition.

Figure 1.- Continued.



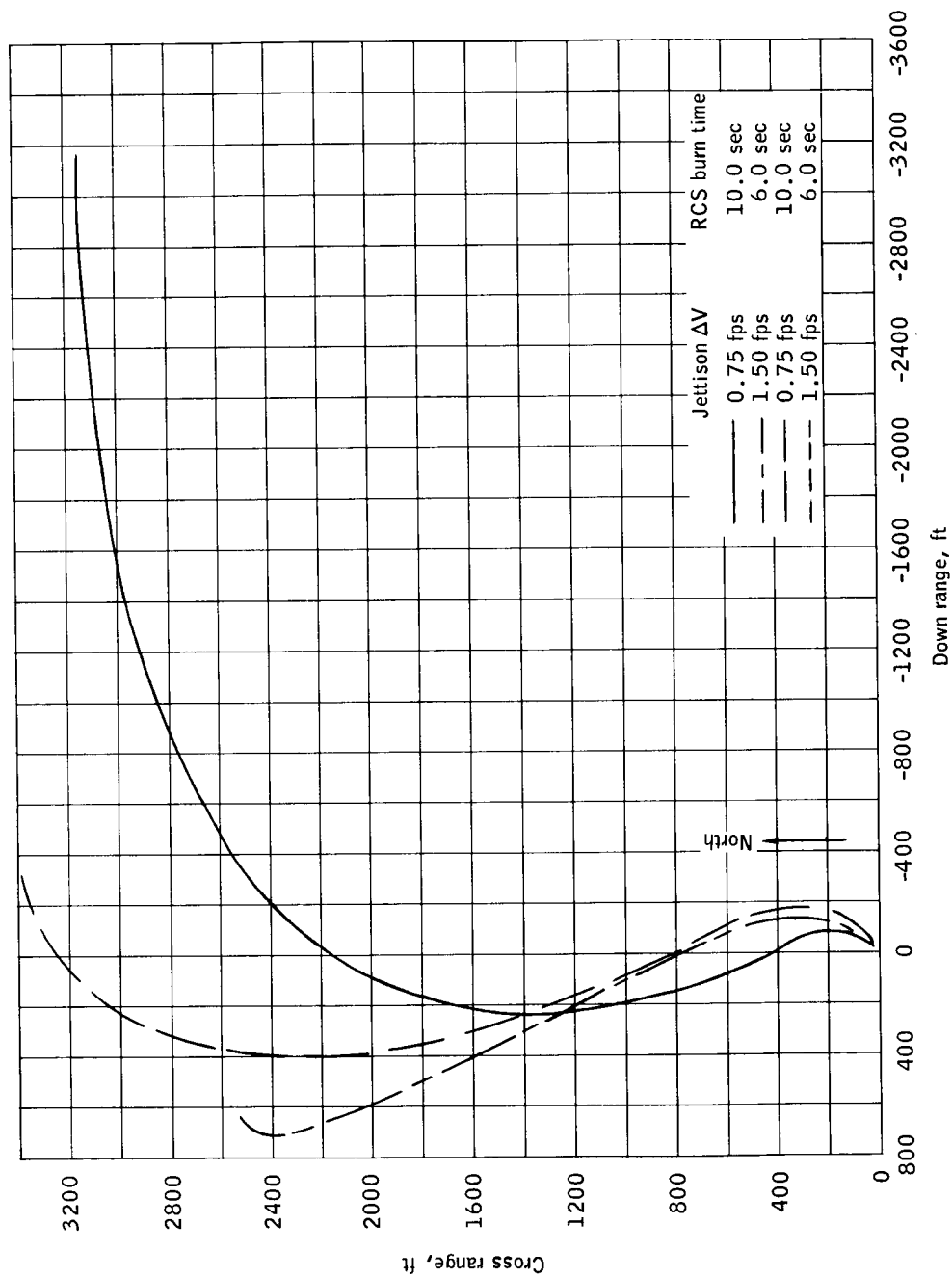
(f) 17 minutes prior to APS ignition.

Figure 1.- Concluded.



(a) Down range versus vertical range.

Figure 2.- Motion of the CSM relative to the LM ascent stage for separation burns initiated subsequent to jettison; varying separation and jettison ΔV 's.



(b) Down range versus cross range.

Figure 2.- Concluded.

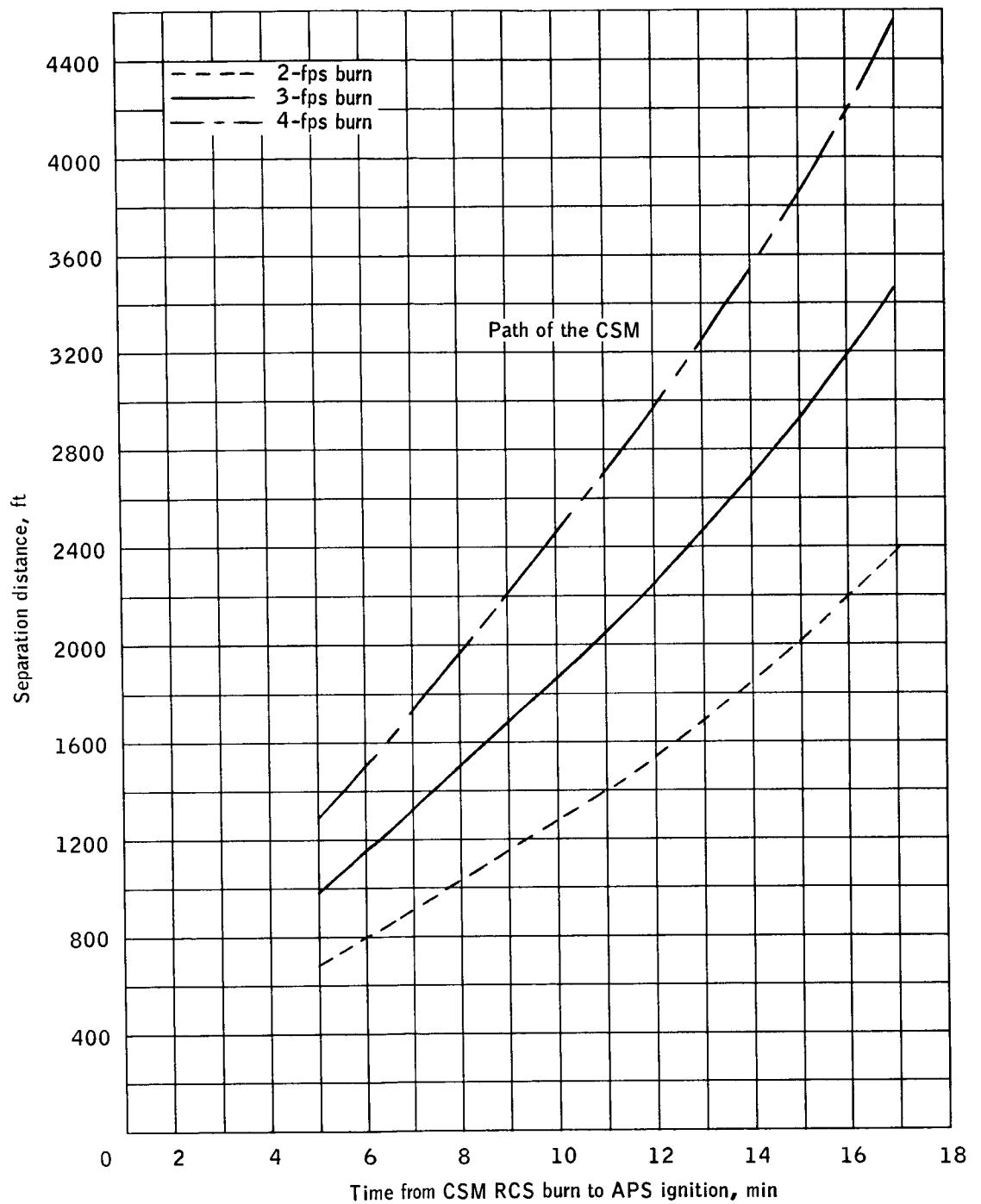
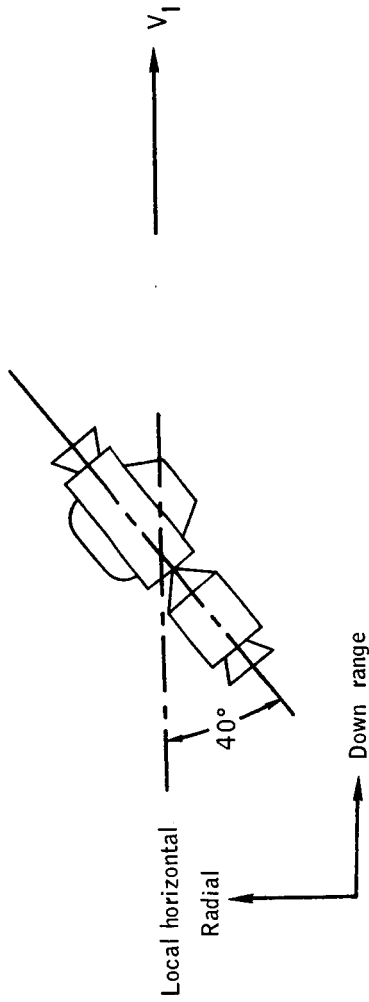


Figure 3.- Separation distance between the CSM and LM ascent stage at APS ignition.

Position and orientation of vehicles at separation
($101^{\circ}30'00''$ g.e.t.)



Position and orientation of vehicles at RCS separation burn
($101^{\circ}38'14''$ g.e.t.)

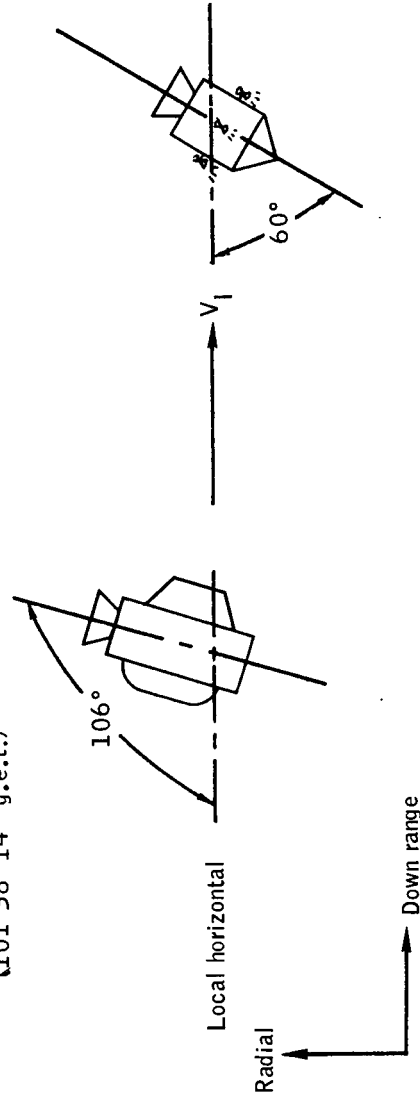
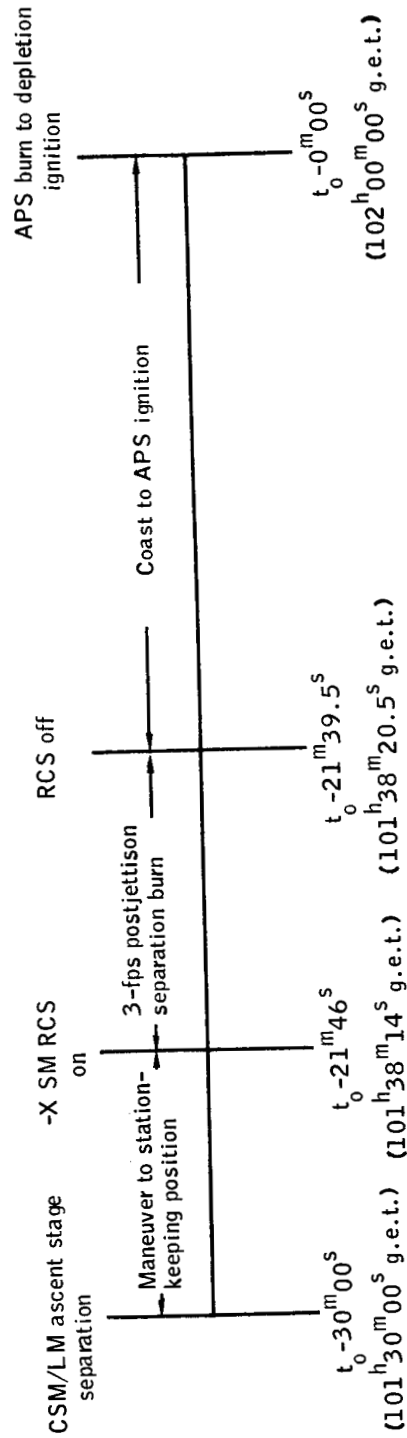


Figure 4. - Position and orientation of the LM ascent stage and CSM at physical separation and at RCS ignition.



NOTE: The CSM stationkeeping position is 100 feet down range of the LM ascent stage velocity vector.

Figure 5. - CSM time line from LM ascent stage separation until the APS burn to depletion ignition.

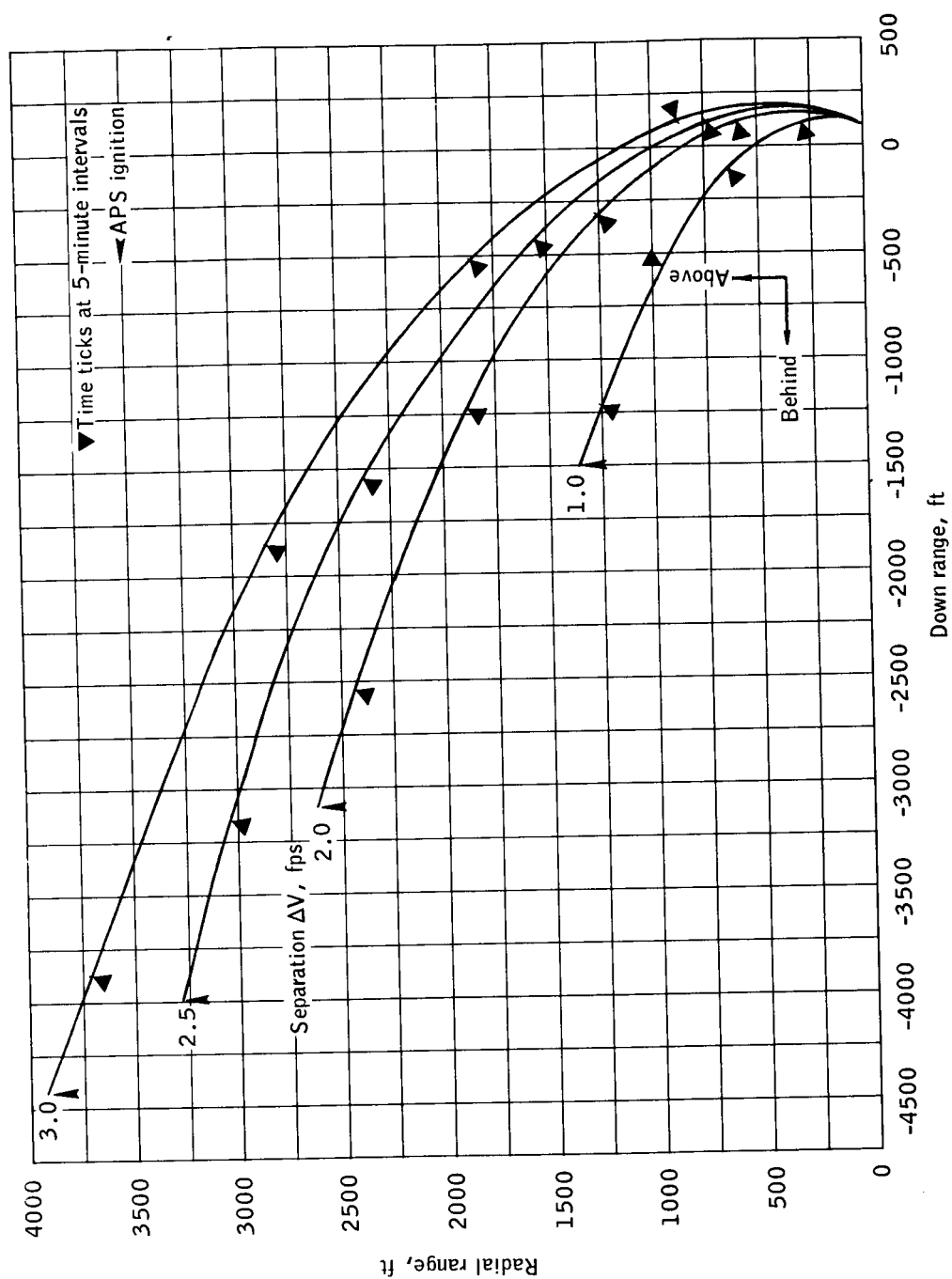


Figure 6.- Motion of the CSM relative to the LM ascent stage following the out-of-plane separation burn (SM RCS) from a stationkeeping position.

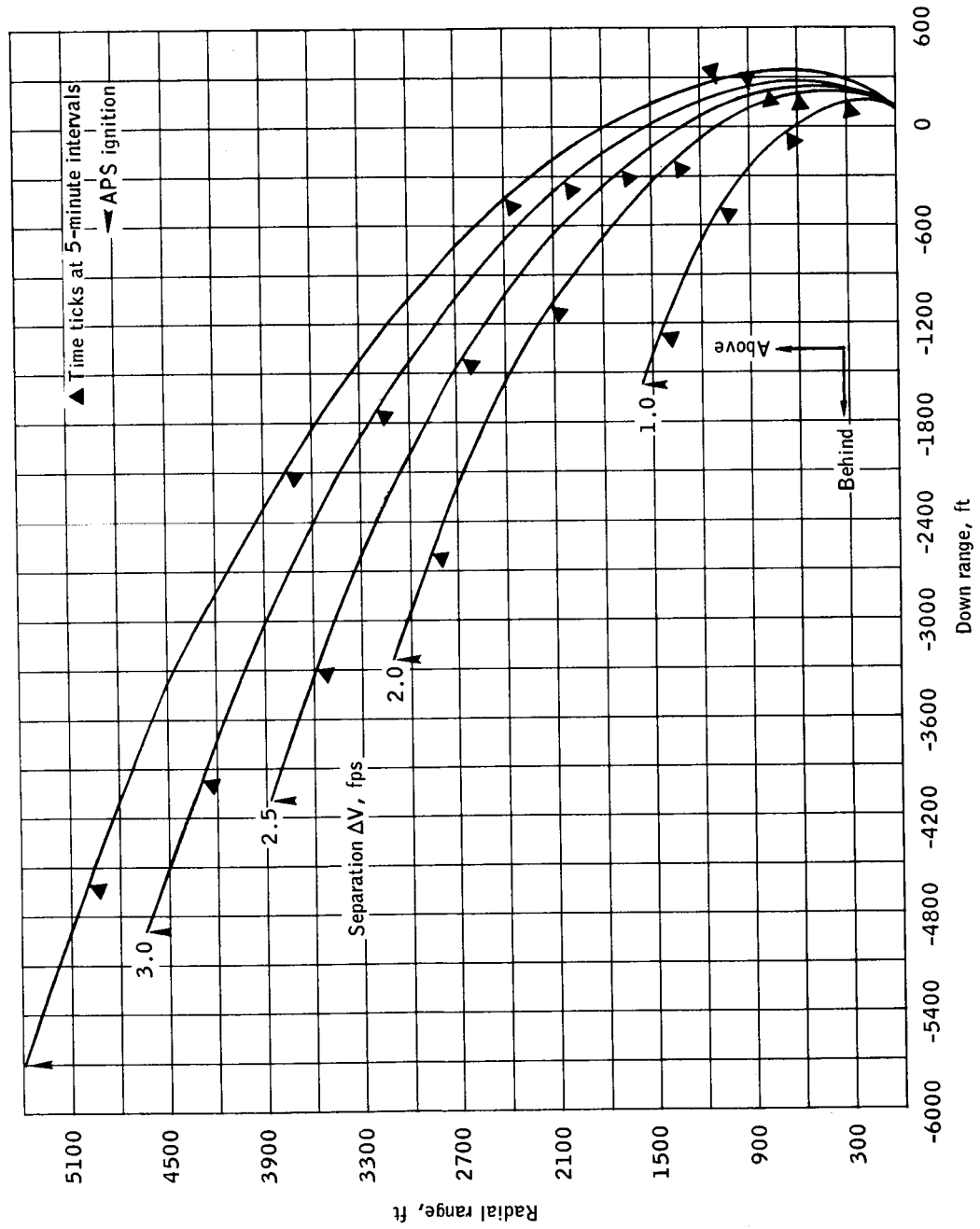
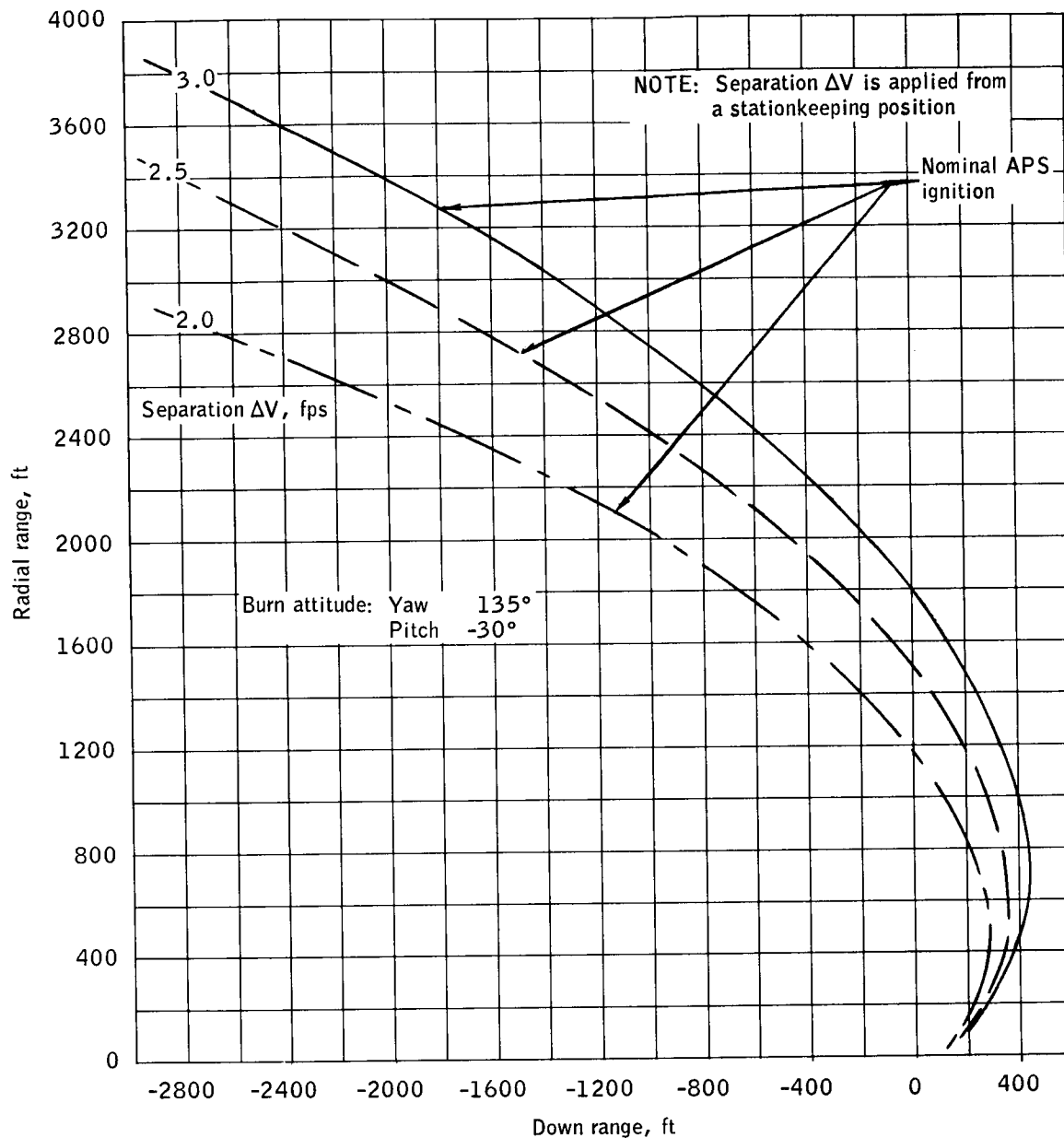
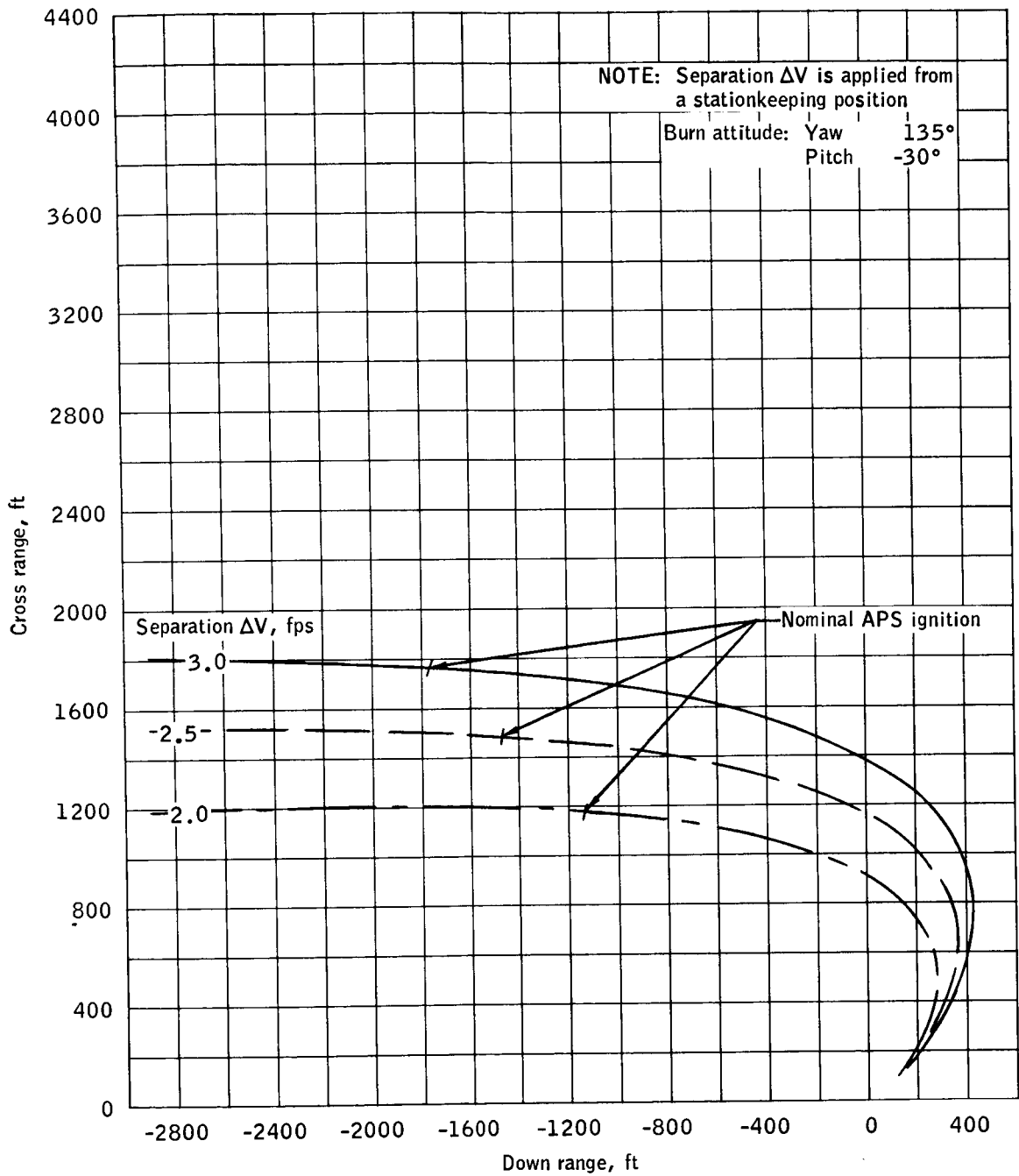


Figure 7.- Motion of the CSM relative to the LM ascent stage following the inplane separation burn (SM RCS) from a stationkeeping position



(a) Down range versus radial range.

Figure 8.- Separation distance of the CSM relative to the LM ascent stage for various separation ΔV 's.



(b) Down range versus cross range.

Figure 8.- Concluded.

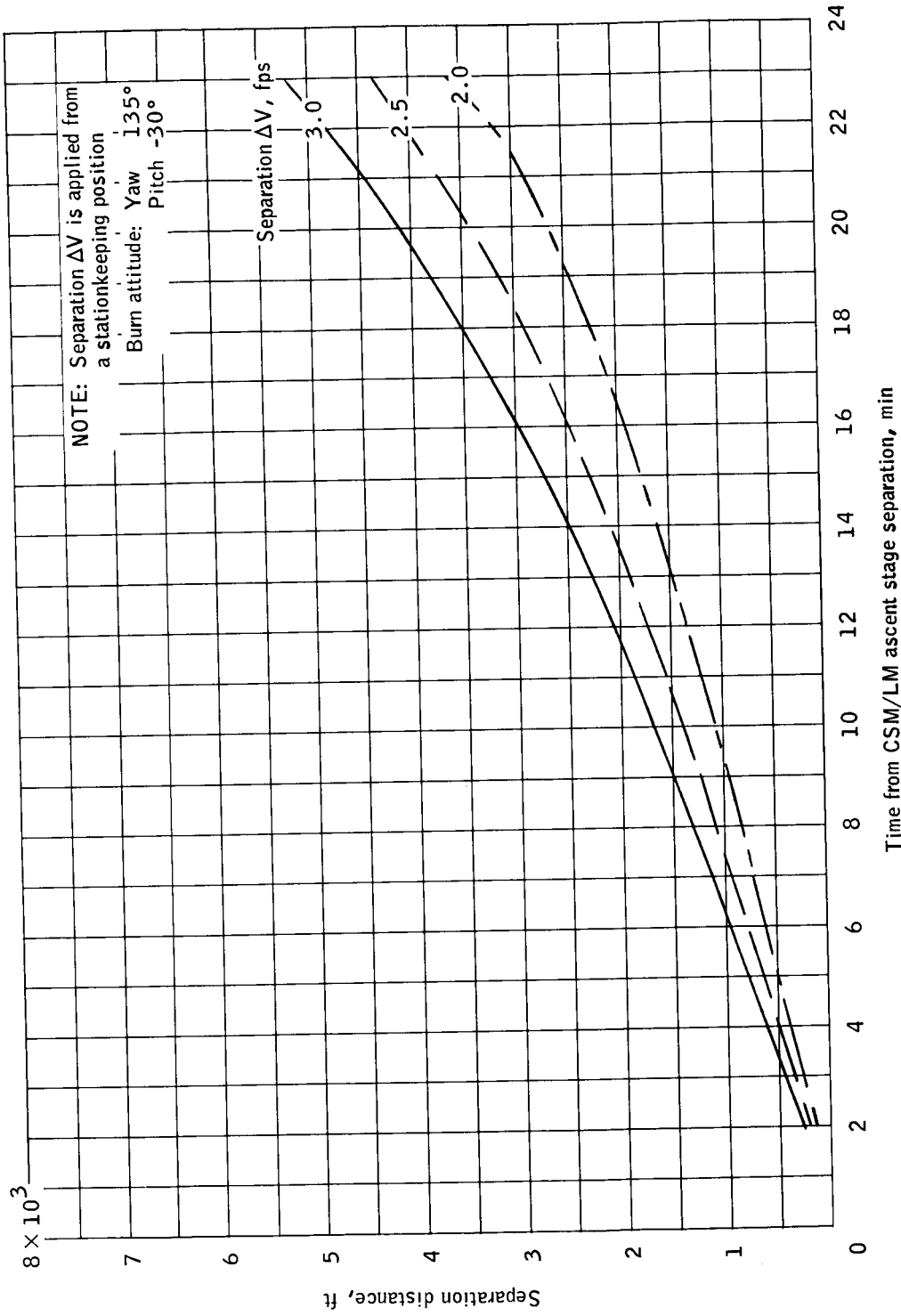


Figure 9.- Total separation distance of the CSM from the LM ascent stage for varying separation ΔV 's applied during stationkeeping versus time from initial separation.